Rec'd PCT/PTO 30 SEP 2004

10/510005

Organ-specific backprojection

The invention relates to a method for the selective imaging of body structures, in which method

- a first image data set is acquired by means of a first tomography method,
- a second image data set is acquired by means of a second tomography method which has a resolution which is higher than that of the first method, the image data of the first and the second image data set coinciding at least partly in space,
- an image is reconstructed from the first image data set, and
- the image data to be imaged is selected by means of the second image data set.

The invention also relates to a device for the selective imaging of body structures in conformity with the described method and to a computer program which is to be executed on a computer and comprises programming means for executing the described steps of the method.

Many tomography methods, notably tomography methods intended for nuclear medicine, such as SPECT (Single Photon Emission Computed Tomography) or PET (Positron Emission Tomography) methods, have the advantage that they provide the viewer of the tomographically formed image with information which goes beyond pure morphology and that in some cases they also visualize physiological processes. Such tomography methods have the drawback, however, that they have only a low spatial resolution so that often only a very poor imaging quality is achieved, notably for fine structures.

In order to avoid this drawback it is known to combine said tomography method with a further tomography method. The second tomography method then images the same region as the previously described tomography method having the low resolution. On the basis of the second tomography method, having a higher resolution, the viewer can then select a given region of interest from the overall image; very exact selection (so-called segmentation) is then possible because of the high resolution of the second method. Subsequently, that region of the low-resolution tomography image, produced by the first, low-resolution tomography method, which corresponds to the selected region of the high-resolution tomographic image is associated therewith by way of image registration, and

exclusively this region is imaged. A method of this kind is described in the article "Iterative Reconstruction of Emission Tomography Data with A Priori Information", Vollmar St. et al., Transactions on Medical Imaging, 199.

This type of combination of two tomography methods has the drawback that the original image acquired by means of the low-resolution tomography method is reconstructed in a conventional manner and that the selection of a detail of this image by means of the high-resolution method takes place only at a later stage. For the conventional reconstruction of the image, the acquired image data are backprojected regularly; during such backprojection the signals measured during the image acquisition by way of forward projection are distributed along the relevant projection line across the entire image region. Because of this distribution across the entire image region, the signals become unsharp and the distance-to-noise ratio becomes small. Experts in this field refer to this phenomenon as “smearing”.

Such smearing is particularly disadvantageous when an iterative method is used for the backprojection, because the smearing and the large image region to be measured necessitate a large number of iterations, thus prolonging the required calculation time and effort.

Therefore, it is an object of the invention to provide a method which enables a higher imaging quality to be achieved for a low-resolution tomography method. It is also an object of the invention to provide a device and a computer program for carrying out said method.

The object is achieved in accordance with the invention in that for the image reconstruction from the first image data set

- first at least one image region to be imaged is selected from the second image data set, and

- subsequently the image reconstruction is calculated from the image data of the first image data set which are situated in the selected image region.

Therefore, the method in accordance with the invention does not calculate a backprojection across the entire image region during the image reconstruction. Instead, an image region which is of interest to the viewer is selected in advance. This selection is performed on the basis of image data which have been acquired by means of a second tomography method having a resolution which is higher than that of the first tomography method. It is notably possible to select regions of the image which contain the object to be

imaged or parts thereof. Furthermore, it is also possible to select a number of regions which may also be coherent, for example, vascular systems.

The backprojection of the image data across the selected image region ensures that the image values are not smeared across the entire image region, but only across a smaller image region, that is, the selected image region. It is thus achieved that the signal-to-noise ratio (SNR) is increased and the quality of the images of the structures to be imaged is enhanced.

The method in accordance with the invention is advantageous notably when the first tomography method is a nuclear-medical tomography method, notably a SPECT method or a PET method. According to such methods, a contrast medium is administered to the patient prior to the tomographic acquisition of the image data. This contrast medium concentrates in given structures of the body, possibly in dependence on given physiological processes, and is imaged with a high contrast by the nuclear medical tomography method. SPECT and PET then have only a low spatial resolution of from approximately 5 to 15 mm. In order to enhance the image quality, use can notably be made of a magnetic resonance tomography method or an X-ray tomography method (MR and CT, respectively). These tomography methods have a resolution in the range of from 0.5 to 1 mm. The use of the method in accordance with the invention is advantageous in particular when a combined CT/PET system or another tomography apparatus combining other tomographic methods is used for the tomographic imaging.

According to an advantageous version of the method the selection of the image region is performed by means of an automatic segmentation method.

In addition to the manual segmentation by the viewer, for example, by defining image boundaries or by selecting image corner points, notably automatic selection methods are advantageously used. According to the automatic selection methods, for example, a selection of the image elements to be imaged can be carried out on the basis of their image values (for example, grey values). For example, it is possible to select given body tissues on the basis of the image values of a computed tomography X-ray image (so-called HU values), said body tissues then being imaged or excluded from imaging. Furthermore, it is feasible for an automatic segmentation method to select regions which have the same or a similar image value and are coherent. Conventional segmentation methods, for example, the so-called regional growing method, can then be used. It may also be arranged that other methods, such as morphological opening or the like, are used for the automatic selection of an image region.

The method in accordance with the invention may ensure in particular that the necessary association of the image data of the first and the second image data set with one another, that is, the so-called registration, is simplified or accelerated by associating exclusively image data of the first image data set which are to be imaged with the second image data set.

It is particularly advantageous to use the method in accordance with the invention when the image reconstruction is carried out by way of iterative backprojection. An iterative calculation then takes place in principle in such a manner that the difference is formed between intermediate results of an image calculation which is periodically performed in the same manner is formed and that the quality of the calculated image is evaluated on the basis of the value of the difference between two successive calculation cycles. Normally speaking, a limit value (convergence criterion) to be reached is then defined.

Because the distance between the signal and the noise value is increased from the very start of the method in accordance with the invention, the method in accordance with the invention enables a reduction of the number of iteration steps required until a convergence criterion is met, that is, in comparison with the conventional method with smearing across the entire image region. Analogously, when the number of iteration steps in the method in accordance with the invention is kept the same as in conventional methods, the image quality of the image formed by means of the method in accordance with the invention can be enhanced in comparison with the image quality of the image reconstructed in a conventional manner.

A further aspect of the invention concerns a device for the selective imaging of body structures, which device includes first tomographic image data acquisition means, second tomographic image data acquisition means, having a resolution which is higher than that of the first tomographic image data acquisition means, means for image reconstruction by backprojection of an image, notably from a first image data set which has been acquired by means of the first tomographic image data acquisition means, and selection means for selecting at least one region of the image data to be imaged, preferably by selection of one or more regions of an image which has been derived from the second image data set. The backprojection means co-operate with the selection means in such a manner that during the backprojection of the image data exclusively the image data are projected which are situated in the selected image region which was selected, by way of the second image data set, by the selection means.

Finally, a last aspect of the invention concerns a computer program with programming means for making a computer carry out the method of claim 1 when the computer program is executed on a computer.

A preferred embodiment of the invention will be described in detail hereinafter with reference to the Figures. Therein:

Fig. 1 shows a flow chart of a method in accordance with the invention,

Fig. 2 is a diagrammatic representation of the co-operation of the means of a device in accordance with the invention, and

Fig. 3 shows a flow chart of a method for iterative backprojection.

As is shown in Fig. 1, in conformity with the preferred version of the method in accordance with the invention first a computed tomography image S1 of a body region is formed; for this purpose several slice images of this body region are acquired at a given distance from one another. This computed tomography image yields a CT image data set R1. Before or after the computed tomography image acquisition, a contrast medium is administered to the patient and a SPECT image S2 is formed, resulting in a SPECT image data set R2. The SPECT image S2 is preferably formed for the same body region and while using the same distance between the slice planes as for the CT image S1.

For the CT image data set R1 and the SPECT image data set R2 there is performed an image superposition or registration operation S3 in which the image data of the CT image data set R1 which are situated in the same geometrical position as the image data of the SPECT image data set R2 are associated with one another. Known methods, for example, fiducial markers can be used for such association. The CT image S1 and the SPECT image S2 need not necessarily cover an identical image region, but it suffices when the two images overlap in the region to be imaged. Furthermore, it is not necessary either for the spacing of the slices of the two images to be the same; it is also feasible that the distance between the slices of one image amounts to an integer multiple of the distance between the slices of the other image.

An image S4 is then reconstructed from the CT image data set R1; customary methods, such as iterative or analytic backprojection, can be used for this purpose. In the CT image R3 thus formed a segmentation of the region S5 to be imaged is performed. This

segmentation can take place in a direction orthogonal as well as in a direction parallel to the projection direction, notably simultaneously in both directions. For example, a region to be imaged can be defined by setting a plurality of corner points of a region to be imaged or by drawing a boundary line around a region. It is also possible to select a plurality of regions to be imaged which are connected to one another or not. Furthermore, it is feasible for the segmentation to be executed automatically by the selection of image elements having a given range of image values or by the selection of coherent regions having a similar range of image values, for example, by way of the so-called region growing method. Furthermore, it is feasible to select structures in the image which are smaller or larger than a given value; customary methods, such as the morphological opening method, can be used for this purpose. It is also feasible to remove one or more image regions from the region to be imaged by means of a filtering operation.

The segmented CT image R4 thus formed is converted into a segmented CT image data set R5 by way of a numerical forward projection S6. During this step, the selected image elements, that is, the segmented region to be imaged, can be associated again with the image data of the original CT image data set in a simplified manner.

The image data of the segmented CT image data set are associated with the image data of the SPECT image data set in a next step S7, resulting in a segmented SPECT image data set R6. This segmented SPECT image data set R6 contains only the image data which are of relevance for the region to be imaged as selected on the basis of the CT image data set. In a further step S8 an image is reconstructed from the segmented SPECT image data set, that is, preferably by iterative backprojection of the segmented SPECT image data set. During this iterative backprojection, the image data is smeared only across the region to be imaged, so regularly across a region which is substantially smaller than the overall image region, thus enhancing the signal-to-noise ratio. The image R7 thus reconstructed has sharper edges and contains more contrast. This reduces the number of iteration steps required for an image whose quality is substantially equivalent to that of an image obtained by means of a conventional reconstruction technique, meaning that the required calculation time and effort are less. Analogously, when the number of iteration steps is the same as that of the conventional method, that is, while spending the same calculation time and calculation effort, an image of significantly higher quality can be formed.

Fig. 2 is a diagrammatic representation of the construction of the device in accordance with the invention and of the programming means of the computer program in accordance with the invention.

The device comprises CT image acquisition means M1 and SPECT image acquisition means M2 which co-operate with image superposition or registration means M4. The CT image acquisition means M1 co-operate with image reconstruction means M3 for the CT image, which means form a CT image from the CT image data set. This CT image is segmented by means of manual segmentation means M5 which are controlled by a user of the device, thus selecting a region to be image.

The manual segmentation means co-operate with means for the numerical forward projection M7 of the selected CT image elements which form an image data set from the segmented image.

Alternatively, as is denoted by the dashed lines in Fig. 2, the CT image acquisition means can co-operate with automatic segmentation means M6 which automatically select given data on the basis of preset parameters or parameters which can be influenced by the user of the device.

The image data selected by means of the automatic segmentation means M6 or the image data produced by means of the numerical forward projection means, co-operate with image reconstruction means M8 for the SPECT image data. The image reconstruction means for the SPECT image data co-operate with the image superposition/registration means so as to associate the selected CT image data with the corresponding, geometrically identically situated SPECT image data.

Alternatively it may also be arranged to perform the image superposition or registration by means of the image superposition means M4 only at an instant after a manual (M5) or automatic (M6) segmentation, and hence also selection of the image elements to be imaged, has taken place. In that case there is no superposition of image regions or registration of image data which are not situated in a region to be imaged.

The image reconstruction means SPECT M8 form a high-quality nuclear medical image of the segmented image region from the selected image data.

The reconstruction of an image from the segmented SPECT image data set S8 by way of iterative backprojection will be described with reference to Fig. 3. The iteration consists in that first, in a backprojection S10, an iteration image R11 is calculated by backprojection of the image data to be imaged of the first image data set R6, selected on the basis of the second image data set or the image R1, R3, after which an iteration image data set R12 is numerically formed from this iteration image R11 in a calculation step S11. This iteration image data set R12 thus represents the result of a numerical forward projection S11 of the calculated image. Subsequently, a difference is formed between the numerically

formed iteration image data set R12 and the first image data set R10. This difference is a measure of the deviation between the iteration image data set R12 and the iteration start image data set R10. If this difference is particularly small, the calculated image does not constitute a significant qualitative improvement relative to the initially calculated image. In this case the iterative calculation process is terminated and the calculated image R11, R7 is output via an output S20.

When the difference does not drop below a predetermined value (the convergence criterion), however, the difference is added to the iteration image data set S11 and a new iteration start image data set R14 is calculated. Using this calculated iteration start image data set R14, representing the new iteration start mage data set R10, subsequently an iteration operation is started again, at the end of which the difference is again used for evaluating the convergence and, should the converge criterion not be satisfied, the difference is again added to the iteration image data set R12 so as to form an iteration start image data set R14.

The above iteration steps are repeated until the convergence criterion is satisfied and the image R11 last calculated is output to the viewer as a segmented SPECT image R7.